STATUS OF MINERAL RESOURCE INFORMATION FOR THE KAIBAB INDIAN RESERVATION, ARIZONA

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SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Some mineral exploration has taken place on tribal lands, but no commercial mineral deposits are known to occur on the Kaibab Indian Reservation. The lands were leased and prospected for uranium during the 1950's. At that time, personnel from the Atomic Energy Commission (now Department of Energy) investigated a uranium prospect in the north central part of the reservation that proved to be noncommercial. A uranium exploration drilling program is currently being conducted west of the reservation. Any data that become available should be evaluated to help determine if any mineralization extends to tribal lands.

Sand, gravel, building stone, and other nonmetallic commodities, used primarily in the construction industry, are found on tribal lands, as well as in other nearby areas. Mining these commodities on the reservation now appears unlikely, unless an outside market can be developed; however, the remoteness of the area, plus the presence of similar deposits closer to markets, substantially reduces the possibility of commercial development of such commodities at this location in the foreseeable future.

Northwestern Arizona, site of the reservation, has had little petroleum exploration. According to available records, no test wells have been drilled on these Indian lands. Oil in noncommercial quantities has been encountered in test wells drilled north of the reservation; thus, oil is known to occur in the region, and if suitable reservoir conditions exist under tribal lands, oil in commercial quantities could be present.

A geological mapping program would help ascertain the petroleum potential of tribal lands. Such a program may be warranted because of evidences of oil in nearby test wells and because there are faults on tribal lands that may have created structural traps for petroleum accumulation.

INTRODUCTION

This report was prepared for the Bureau of Indian Affairs by the Bureau of Mines and the U.S. Geological Survey under an agreement to compile and summarize available information on the geology, mineral resources, and potential for economic development of certain Indian lands. Source materials include published and unpublished reports, as well as personal communications. No fieldwork was done.

Northwest Arizona is a sparsely populated, open, high plateau region about 1 mile above sea level. The Kaibab Indian Reservation, a small part of this region, is located in both Mohave and Coconino Counties, Ariz., and borders on Kane County, Utah (Figure 1). Tribal lands, occupied by the Kaibab Band of the Paiute Tribe, encompass 120,413 acres, including about 107,000 acres in Mohave County, and about 13,000 acres in the southeast part of the reservation in Coconino County. Lands within the reservation are tribally owned; there are no allotted lands.

Two non-tribal enclaves exist within the reservation--Pipe Spring National Monument, consisting of 40 acres, and Moccasin, a 480-acre, non-Indian community centered around Moccasin Springs. Kaibab, the population center of the

reservation, has about a dozen homes. Sixmile Village is the only other community on tribal lands. Only 208 Indians resided on the entire reservation in 1976 (Arizona Office of Economic Planning and Development, 1977).

The reservation boundary is 2 miles west of Fredonia, Ariz. (pop. 797), on Arizona State Highway 389. Seven miles north of Fredonia is Kanab, Utah (pop. 1,341), the only other community close to the reservation (U.S. Department of Commerce, 1970).

Access to the area is from the east or west via state route 389. U.S. alternate route 89 passes through Fredonia (population 798 as of 1976). Various paved and unpaved roads as well as trails traverse the Reservation (Figure 1). By road, the reservation is about 110 miles from either St. George (population 7,097) or Cedar City (population 8,946), Utah, and by air it is 230 miles north of Phoenix (population 863,357).

Average total precipitation in the area is 9.38 inches. Average minimum January temperature is 18.9ºF, and maximum July temperature is 92.9ºF.

MAPS

Two U.S. Geological Survey 15' quadrangle maps, Colorado City (formerly Short Creek), Ariz., and Fredonia, Ariz., show the topography of the area. The topography is also shown in less detail on the Survey's Grand Canyon map (scale 1:250,000). These maps do not, however, depict present cultural features because they are 1954 editions. The ownership status of land in Arizona is presented on the U.S. Bureau of Land Management Areas of Administrative Responsibility of Federal Lands Map, 1964. Road maps for most counties of Arizona are available through the Arizona Department of Transportation. Air photos are also available. Both the U.S. Geological Survey and the Army Map Service have photo coverage of the area. Photos can be ordered from the EROS Data Center in Sioux Falls, S. Dak.

PHYSIOGRAPHY

Arizona is divided roughly into two physiographic provinces by the Mogollon Rim that extends diagonally across the State from northwest to southeast. The southwest half of the State lies within the Basin and Range physiographic province, where more than 90 percent of the population, agricultural acreage, and mineral resources are concentrated. The rest of the State, including the reservation, is in the Colorado Plateau physiographic province. This province contains all of the State's oil and natural gas, and most of its uranium and coal.

The reservation occupies portions of two different sections of the Colorado Plateau physiographic province. The northern half is in the Vermilion Cliffs cuesta section, and the southern half lies in the Kaibab Plateau section, one of several linear plateaus north of the Grand Canyon that were formed or influenced by differential displacement along regional north-south faults or monoclines (Howard and Williams, 1972). The two sections are separated by the south-facing Vermilion Cliffs.

The Moccasin Mountains occupy the rugged, northwest part of the reservation. Along the southern edge of these mountains are the prominent

Vermilion and Shinarump Cliffs. The southern half of the reservation is made up of open, rolling, sparsely covered grasslands that slope southeastward. Highest elevation (7,058 feet) on tribal lands is Ed Lamb Point, near the central northern reservation border. Lowest point (4,400 feet) is on the south boundary at Ranab Creek. This creek, the major drainage of the area, marks the boundary between Mohave and Coconino Counties across the southeastern corner of the reservation. Ranab Creek joins the Colorado River about 30 miles south of the reservation.

The few intermittent streams on the reservation display a dendritic drainage pattern in their generally deeply entrenched headwaters; Moccasin Wash and Aulson Canyon are examples. These same drainages, emerging onto the plain, are mostly shallow washes; however, near the southern boundary of the reservation, Ranab Creek follows an entrenched and often meandering course in a steep canyon that continues to the Colorado River.

PRESENT STUDY

A generalized geologic view of the reservation is presented on the geologic maps of Mohave and Coconino Counties. These two maps are part of the county geologic map series of Arizona published by the Arizona Bureau of Mines and the University of Arizona (1959, 1960). Wilson (1958) presents a detailed study of the Rayenta and Moenave Formations in the Vermilion Cliffs region. His report serves as a basis for much of the geology presented here.

Locations and descriptions of mineral deposits are found in U.S. Geological Survey Bulletins and Mineral Resource maps, on Arizona Bureau of Mines maps, and in the CRIB (Computerized Resource Information Bank) files. These files contain information for all known mines and prospects. In particular locations, ore mineralogy, geologic relations, production, and references are noted when available. Additional references are at the end of the report.

GEOLOGY

Previous Geologic Investigations

The results of the first investigation of the geology in northern Arizona are presented by Newberry (in Ives, 1861, Part IV). Various members of the Wheeler and Powell Surveys investigated parts of California, Nevada, Utah, Arizona, and New Mexico between 1870 and 1880. Marvine made a traverse south from St. George to the Grand Canyon and described physiographic and geologic features which are quite similar to those encountered in the area of the Reservation. G. K. Gilbert and E. E. Howell made a reconnaissance geologic map of the Vermilion Cliffs area during this time and Gilbert measured three sections there.

The most detailed early work in the reservation area was done by Dutton (1882). His map and monograph include discussions of the Vermilion Cliffs geology, including the Pipe Spring area. Cross (1908) discusses the Shinarump group in Kanab Canyon. Walcott (1880) presents a brief description of the Permian and Paleozoic rocks in Kanab Valley. A bibliography on early geologic investigations in northern Arizona is presented by Darton (1910).

More recent work dealing directly with the Reservation land is scarce. The major study in the area is concerned with the Kayenta and Moenave Formations in the Vermilion Cliffs region. In this study Wilson (1958) gives the most detailed geologic picture produced to date for the area. Many similar studies have been prepared for localities throughout southern Utah and northern Arizona. Most of the information in these is applicable to the Kaibab Reservation. Wilson (1958) presents a complete bibliography of these studies.

Stratigraphy

Introduction

The Kaibab Indian Reservation is underlain by Permian through Jurassic sedimentary rocks. Most of the section is Triassic in age. These rocks are well known and well studied elsewhere in the southwest. For more detailed information concerning correlation and description reports by Wilson (1958), McKee (1938, 1954), and the references cited therein should be consulted. The formations are listed in stratigraphic sequence on the geologic map of the reservation (Figure 2).

Permian

Kaibab Limestone.--The oldest rocks exposed on the Kaibab Indian Reservation are part of the cliff-forming Kaibab Limestone. Only several square miles of this formation are exposed on the reservation. The Kaibab Limestone forms the rim of the Grand Canyon in many places. It is primarily a light- to dark-gray limestone or cherty limestone, but contains some lime sandstone, dolomitic limestone, some red beds, and gypsum layers as well. Brachiopod, bryozoan, sponge, and coral fossils are commonly found in the calcium carbonate layers. The many rock types found within the formation indicate a rapidly changing environment of deposition. The principal environment was shallow-water marine, but shallow coastal lagoon deposits are represented as well. The fossils indicate brackish as well as normal sea-water conditions. The formation ranges from 250 to 500 feet thick. Its contact with the overlying Moenkopi is everywhere unconformable. Subaerial erosion prior to deposition of Moenkopi sediments is indicated.

Triassic

Moenkopi Formation.--The Moenkopi Formation crops out on about half of the reservation land. The entire southeast corner of the area, except for a small outcrop of Kaibab Limestone, is underlain by the Moenkopi. Thickness of the Moenkopi varies widely but systematically across Arizona. At Fredonia the formation is 854 feet thick. In this part of northern Arizona, the Moenkopi is primarily composed of sandstone, siltstone, mudstone, and limey gypsiferous red beds. In northern Arizona considerable amounts of gypsum are common. Six lithologic members of the formation have been delineated. It is typically red to red-brown. The Moenkopi Formation forms benches, platforms, and low domes. Structures in the red beds suggest deposition on mudflats and deltas in subaerial environments. The unconformity at the base of the Moenkopi indicates missing strata and a hiatus equivalent to tens of millions of years. The

top of the formation is also marked by an unconformity. Long periods of subaerial erosion prior to deposition of the Shinarump Conglomerate are indicated (McKee, 1954).

Shinarump Conglomerate.--The Shinarump Conglomerate is named for outcrops that cap the Shinarump Cliffs on the Kaibab Indian Reservation. These cliffs are about 200 feet high and strike northeast across the north end of the Kaibab Plateau. The conglomerate itself is between 70 and 130 feet thick in the Vermilion Cliff region and consists of yellow to gray, lenticularly bedded, coarse-grained, conglomeratic sandstone. The deposit is blanket like on top of the Moenkopi, but is locally absent. The mapped outcrop pattern is irregular because the Shinarump Cliffs have been breached by various intermittent streams. The Shinarump conglomerate underlies about 10 percent of the reservation.

Chinle Formation.--The Chinle Formation crops out between the top of the Shinarump Cliffs and the bottom of the Vermilion Cliffs in dissected rounded slopes. Like the Moenkopi, it is not very resistant to weathering. The Chinle consists of variegated grayish, white, reddish, and yellowish fine-grained siltstone and claystone with lesser amounts of limestone, sandstone, and lenticular conglomerate (Wilson, 1958). The Chinle is from 500 to 600 feet thick in the Vermilion Cliffs. The lenticular sandstones contain abundant fragments of silicified wood. The top of the formation is marked by a slight erosional unconformity below the overlying Glen Canyon Group. The Wingate sandstone, the basal formation in the Glen Canyon Group elsewhere, is missing on the Kaibab Indian Reservation. The contact with the overlying Moenave Formation is characterized by a chert-pebble conglomerate in places.

Triassic-Jurassic: Glen Canyon Group

Moenave Formation.--The Moenave Formation is highly resistant to weathering and forms the basal sandy part of the Vermilion Cliffs. Its thickness is relatively constant throughout the area. At Pipe Spring it is 330 feet thick. In the Vermilion Cliffs, three members of the formation can be discerned. The Dinosaur Canyon Member is composed of pale-reddish-brown to moderate-reddish-orange siltstone and very fine grained sandstone with subordinate claystone. It is easily distinguished from the underlying Chinle, which is gray or grayish red. The Whitmore Point Member consists of thin beds of pale-red to light-brown siltstone and gray to grayish-red claystone with limestone. A prominent, gray slope 60-80 thick below the massive maroon-colored ledge of the overlying Springdale Sandstone Member marks the Whitmore Point Member. The Springdale Sandstone Member is the upper member of the Moenave Formation. It forms a prominent vertical cliff of pale-red to light-brown variegated to purple and yellow, fine-grained, crossbedded sandstone with subordinate pale-reddish-brown shale and conglomerate. Average thickness of the Springdale Sandstone Member is 150 feet. The various members of the Moenave Formation were deposited in a fluvial environment. The contact with the overlying Kayenta Formation is usually sharp.

Kayenta Formation.--The Kayenta Formation is lithologically the most variable unit of the Glen Canyon Group in the Vermilion Cliffs region. The predominant rock types are siltstones and very fine grained sandstones of fluvial origin. The thickness of the formation is variable from place to place. At Pipe Spring the Kayenta is 714 feet thick. The overlying Navajo Sandstone is complexly intertongued with the Kayenta Formation. All deposits between the top of the Springdale Sandstone Member of the Moenave Formation and the bottom of the Navajo Sandstone are classified as the Kayenta Formation.

Navajo Sandstone.--In the Vermilion Cliffs region, the Navajo Sandstone is the more prominent and striking formation in the Glen Canyon Group, forming a sheer cliff of massive sandstone, hundreds of feet high. Fine-grained, reddish to white sandstone, cross stratified on a large scale, is the principal constituent of this formation. The Navajo is 1,210 feet thick at Kanab and reaches a maximum thickness of 2,280 feet at Zion. In some places the Navajo is characterized by a white upper part and a pale-reddish to buff lower part. This condition is variable however. The Navajo Sandstone was deposited in an aeolian environment, in contrast to the fluvially deposited rocks which underlie it (Wilson, 1958).

Structure

As in most of the strata of the Colorado Plateaus province, the sedimentary rocks of the Kaibab Indian Reservation have been very little deformed. They have been uplifted thousands of feet, but have not been tilted or folded. The rocks in the Vermilion Cliffs have a regional dip to the north and east, which usually does not exceed 5º. Monoclines and high-angle normal faults are the main structural features crossing the reservation.

The Sevier fault intersects the Vermilion Cliffs at Pipe Spring, along its north-south trend. According to Gregory (1950), the fault extends for 200 miles between the Unikaret Plateau in the south to central Utah to the north. Through most of its length the Sevier fault consists of a single strand, but at Pipe Spring a subsidiary strand branches off to the west and then rejoins the main strand about 15 miles north. The west side of the Sevier fault has been downthrown between 1,850 and 2,380 feet. The western branch has a down throw amounting to between 60 and 180 feet. Gregory (1944) indicates that movement along the Sevier fault began in Late Tertiary time, as all Tertiary beds, including Pliocene deposits, have been cut and displaced the same amount. The structure map of Pierce, Keith, and Wilt (1970) indicates a monocline dipping northwest and striking northeast through the southeast corner of the Reservation.

MINERAL RESOURCES

Known mineral resources on the Kaibab Indian Reservation are scarce. The most noteworthy potential resource is uranium, but all previous investigations in the area indicate that even this occurrence is not economically significant. Small shows of copper have also been noted, and these probably fit into the same economic category as the uranium. Gypsum, limestone, sandstone, and sand

and gravel are also present, and may possibly be of economic importance.

Oil exploration in the vicinity of the reservation has been very limited. Nearest petroleum production is from the Virgin field in Utah, the oldest oilfield in that State. In Arizona, exploration interest has centered around the Black Mesa Basin in the northeastern quarter of the State. Most recent oil exploration has been northwest of the reservation in Utah.

Metallic Mineral Resources

The only known metallic element on the reservation is copper. Trace amounts of it have been found throughout the Colorado Plateau sedimentary rocks in carbonate minerals, but have not resulted in any significant production. Azurite and malachite are commonly associated with shows of uranium.

A small ore deposit of 113 tons, containing 2,700 pounds of copper and 14 ounces of silver, was mined in 1942 from a claim on Cedar Ridge (U.S. Bureau of Mines, 1943, p. 244). Cedar Ridge is a curved, northeast-trending ridge about 4 miles west of Kaibab Tribal lands. The deposit, as described by N. B. Roundy, one of the original locators of the claim, consisted of copper-silver replacement in a large fossilized tree trunk, and was found in approximately NE½NE½ sec. 25, T. 40 N., R. 6 W., Mohave County, Ariz. In spite of trenching and drilling efforts, no similar occurrences were found in the area. The stratigraphic position of the deposit, as described recently by a Bureau of Land Management geologist who investigated the site, was in the Petrified Forest Member of the Chinle Formation.

Lawson (1913) stated that gold was widely disseminated throughout the clayey portion of the Shinarump and Chinle Formations. Hydraulic mining was once employed outside Mohave County in an unsuccessful effort to recover this gold. No other literature is available that deals with this subject; it is unlikely that gold occurs as a resource at the Kaibab Indian Reservation. No placer gold has been reported to have been produced from northwest Arizona.

Energy Resources

Coal, oil, natural gas, and uranium are the energy resources. Of these, only uranium has been found on the Kaibab Indian Reservation.

Uranium

In the 1950's, uranium exploration was widespread in the Colorado Plateau area. Most of the early uranium production was obtained from the Shinarump Conglomerate and the Chinle Formation in the Four Corners region. The Shinarump Cliffs northeast of the reservation are the type locality for the Shinarump Conglomerate. These cliffs extend southwestward onto the reservation, where the exposures generally face southeast.

Personnel from the Atomic Energy Commission (AEC) examined uranium prospects in the reservation area, and their fieldwork is reported in RME-158, "Preliminary Reconnaissance for Uranium In Mohave County, Arizona 1952 to 1956," June 1970. An undated preliminary report

in this publication (File SL-124, p. 41) notes that a lease for reservation lands was granted to Verdi Development Corp., Hollywood, Calif., and that AEC personnel made a radiometric examination of outcrops in the leased property. The location cited in the report is "sec. 67, T. 41 N., R. 3 W." Most of the reservation is unsurveyed, including this area. The prospect was described as a small, hand-dug pit near the base of the Vermilion Cliffs (in the Petrified Forest Member of the Chinle Formation) that consisted of "Small nodules and seams of yellow uranium mineral in pink to white gypsum. Minor radioactivity from yellow uranium mineral associated with silicified logs. Also some sooty black material in the gypsum that is quite radioactive." A grab sample from the deposit had a calculated U_3O_8 content of 0.518 percent, and 0.53 percent equivalent U_3O_8, indicating that uranium in the sample was close to equilibrium.

Several properties near the west boundary of the reservation have been investigated for uranium. Examinations of the Rainbow Uranium Claim in sec. 24, T. 40 N., R. 6 W., Mohave County, were made in 1952 by mining engineers from the Bureau of Mines and geologists from the Geological Survey. The Bureau examination was conducted by W. E. Young and J. F. Haynes for the Defense Minerals Exploration Administration (docket DMEA 2589) and pertained to a proposed mineral exploration assistance loan (U.S. Bureau of Mines, 1952). The loan was not made.

An examination and report on the same property was made independently by H. S. Granger and R. B. Raup (1970) of the Geological Survey. That report notes that a grab sample was taken from a lense within the Shinarump Conglomerate at the point of maximum radioactivity. The flat-lying lense was less than 4 feet in thickness and about 75 feet long. Chemically assayed, the sample contained 0.024 percent U_3O_8.

An "old copper prospect" on Cedar Ridge (possibly the same property described in this report under "Copper") was examined for uranium by the AEC on May 21, 1953 (RME-158, File R-R-106, p. 140). No legal description was given, but a subsequent report indicated the property, "Last Chance 1 to 8," to be in section 25. Four surface chip samples had calculated U_3O_8 contents ranging from 0.012 to 0.020 percent.

By 1955, the Last Chance 1 to 8 had been renamed "Rainbow Claims," and a detailed reconnaissance was made by AEC personnel (RME-158, File R-Rs-106, pp. 141-142). The property then had been drilled extensively with no indications of significant radioactivity. The report, describing drill cuttings as "...typical of the Petrified Forest member of the Chinle formation," further stated that "A few loads of ore of unknown grade have been shipped from the Radon group of claims a couple of hundred yards to the north." The Radon claims thus probably would be in section 24.

On July 22, 1954, an AEC examiner inspected the Radon 6 and 7 claims (RME-158, R-R-204, p. 42), described as being in sec. 22, T. 40 N., R. 6 W., on Cedar Ridge, although this location is about 1 mile west of the ridge. "Well-silicified logs" were present, but no increased radioactivity above the background count was noted.

Other prospects in the reservation area were examined by AEC personnel, including the "Little Three #l" group of eight claims in sec. 6, T. 39 N., R. 3 W. (RME-158, File R-R-205, p. 40), and the

Iris claims in sec. 4, T. 38 N., R. 6 W. (RME-158, File R-R-255). The prospects were found to contain little or no mineralization and displayed no significant radioactivity.

During the spring of 1978, a major mineral company drilled an area west of the reservation in Cane Beds Valley south of Colorado City. The tests reportedly were drilled to the base of the Shinarump in search of uranium, but test results have not been released.

Petroleum and Natural Gas

If suitable reservoir conditions exist, oil may possibly be present on the Kaibab Indian Reservation. Northwestern Arizona, including the reservation, has had limited petroleum exploration and no production. The nearest oilfield is the Virgin field in SW¼ sec. 12 and W½ sec. 13, T. 41 S., R. 12 W., Washington County, Utah, about 20 miles northwest of the reservation. The field was discovered in 1907 and produces from the shallow Rock Canyon (Timpoweap?) Member of the Moenkopi Formation. Oil is stratigraphically trapped in either a thin limestone or thin conglomerate bed (Bahr, 1963).

First oil exploration drilling in northwestern Arizona was the No. 1 State, drilled in 1909 by Arizona-Utah Consolidated (Arizona Well Information, 1972). The well was drilled to a depth of 936 feet in sec. 31, T. 42 N., R. 8 W., Mohave County, about 21 miles west of the reservation. Closest test well to the reservation was the T. W. George No. 1 Federal in sec. 12, T. 40 N., R. 6 W., Mohave County, about 3½ miles west of the tribal lands. Drilled in 1957, the test reached a total depth of 2,202 feet in the Kaibab Formation. Incidentally, the top of the Shinarump was reportedly reached at a depth of 675 feet in this well. If no faulting is present, the Shinarump probably was not at the surface in sections 24 and 25 of this township, as indicated in two earlier uranium examination reports. The geologic map of Arizona, published by the State Bureau of-Mines and the U.S. Geological Survey, shows the presence of the Chinle Formation, and no faulting at this location.

Exploration for petroleum in northwestern Arizona has been limited to a large degree by the fact that the Colorado River gorge exposes the entire sedimentary section that is present in this region; however, local traps may exist. More than 200 feet of oil staining and fluorescence were encountered during exploration drilling approximately 6 miles north of the reservation in the J. Ray McDermott No. 1, in C SW¼SW¼ sec. 2, T. 43 S., R. 8 W., Kane County, Utah (Tapp, 1963). C. D. Swapp (1961) confirms that many of the other test wells drilled in the area have shown evidences of oil. Mr. Swapp also notes in the same article that "Northwestern Arizona has long been considered a highly promising potential oil and gas producing province," and he states, "I believe there is a chance for oil and gas in possible traps along the Sevier Fault."

A publication by the Arizona Bureau of Mines on oil, gas, and other energy minerals contains the following closing comment: "In particular, northwest Arizona needs additional effort to test pre-Permian objectives at depth ranging from 3,000 to approximately 6,000 feet along a belt in Arizona within 25 miles of the Utah border." (Pierce, Keith, and Wilt, 1970).

Other Minerals

Coconino County is known for high-grade flagstone, most of which is quarried west of Flagstaff near Ash Fork about 100 miles south of the reservation. The stone is shipped to California (U.S. Bureau of Mines, 1953).

Permits reportedly have been issued for mining and local use of sand and gravel on tribal lands. Sand and gravel deposits occur throughout much of the region, but utilization is confined to road construction and other local markets. Additional nonmetallic resources that occur on tribal lands include building stone, bentonite, gypsum, and limestone, but similar deposits are available elsewhere at points closer to markets, rendering tribal deposits uneconomic at this time.

Bentonite

Bentonite is montmorillonitic clay produced by alteration of volcanic ash or tuff. When this clay has a high swelling capacity and is fine grained, it is useful as drilling mud, as bonding material for foundry sands, as impervious lining for reservoirs, and in many other ways. The Chinle Formation contains billions of tons of this material, but most of it occurs as impure bentonitic shale. Some beds of low-grade bentonite in the Chinle may possibly have potential value. No ore-grade bentonite has been produced in Mohave County.

Gypsum

Gypsum is hydrated calcium sulfate ($CaSO_4$ $2H_2O$). Its dehydrated equivalent is anhydrite ($CaSO_4$). Bedded deposits of each are thought to result from evaporation of saline water and concentration of salts. Calcined gypsum is widely used in the construction industry. Gypsum and anhydrite are also used as fertilizer and additives in agriculture.

On the Colorado Plateau, gypsum is found associated with shallow water deposits, where it occurs in irregular lenses and beds. Northern Mohave County has produced gypsum from the Kaibab Limestone in lenses 1-4 feet thick in associated red beds. In the Kaibab Reservation the Kaibab Limestone is the only formation bearing appreciable amounts of gypsum, but because little Kaibab Limestone crops out on Reservation land, there is little possibility of finding commercially significant amounts of gypsum.

Limestone

Limestone and the lime derived from it have a great number of uses in industry (Key, 1965). Kaibab Limestone is predominantly a limestone, but its siliceous nature relegates it to use as crushed stone for aggregate. Some Kaibab Limestone and dolomite is suitable for use as construction stone, but the transport costs would prohibit sale in large urban markets of the west.

Sandstone

The principal use of sandstone is as construction material. The massive basal part of the Moenkopi Formation has been quarried for building stone in Navajo and Coconino Counties where exposures are accessible and contain good stone.

The Moenkopi on the Kaibab Reservation is probably too far from urban centers to be of any marketable value at this time.

Petrified Wood

Numerous petrified logs have been found in the Chinle Formation. Pieces of petrified wood may be sold locally to tourists, but no market exists to warrant extensive mining. Petrified wood is common throughout the Colorado Plateau so transport of the material for sale is unwarranted.

Sand and Gravel

Deposits of sand and gravel occur in many of the dry washes on the Reservation. The worth of this material is its local use as road material and concrete mix.

Potential Mineral Resources

Of the nonmetallic minerals, bentonite and gypsum are the most likely resources. Because of the quality of the deposits and prohibitive transportation costs, the others cannot be considered resources at present. The presence, quality, and quantity of gypsum and bentonite deposits will have to be established before their value can be determined.

Of the metallic minerals, only copper is a possible resource, although at this time its potential is low.

Of the energy minerals, uranium and petroleum may be present as a resource. The occurrence of uranium at one place on the reservation, and in a number of surrounding localities, offers hope of its existence in minable quantities of the reservation. If suitable reservoir conditions exist petroleum could be present.

RECOMMENDATIONS FOR FURTHER WORK

Further cautious exploration for uranium deposits in the Chinle and Shinarump Formations might possibly prove fruitful at some time in the future. Detailed exploration for bentonite in the Chinle Formation and for gypsum in the Kaibab Limestone might also be worthwhile, but even if significant deposits exist they would be far from potential markets. Other than these possibilities, no exploration is recommended.

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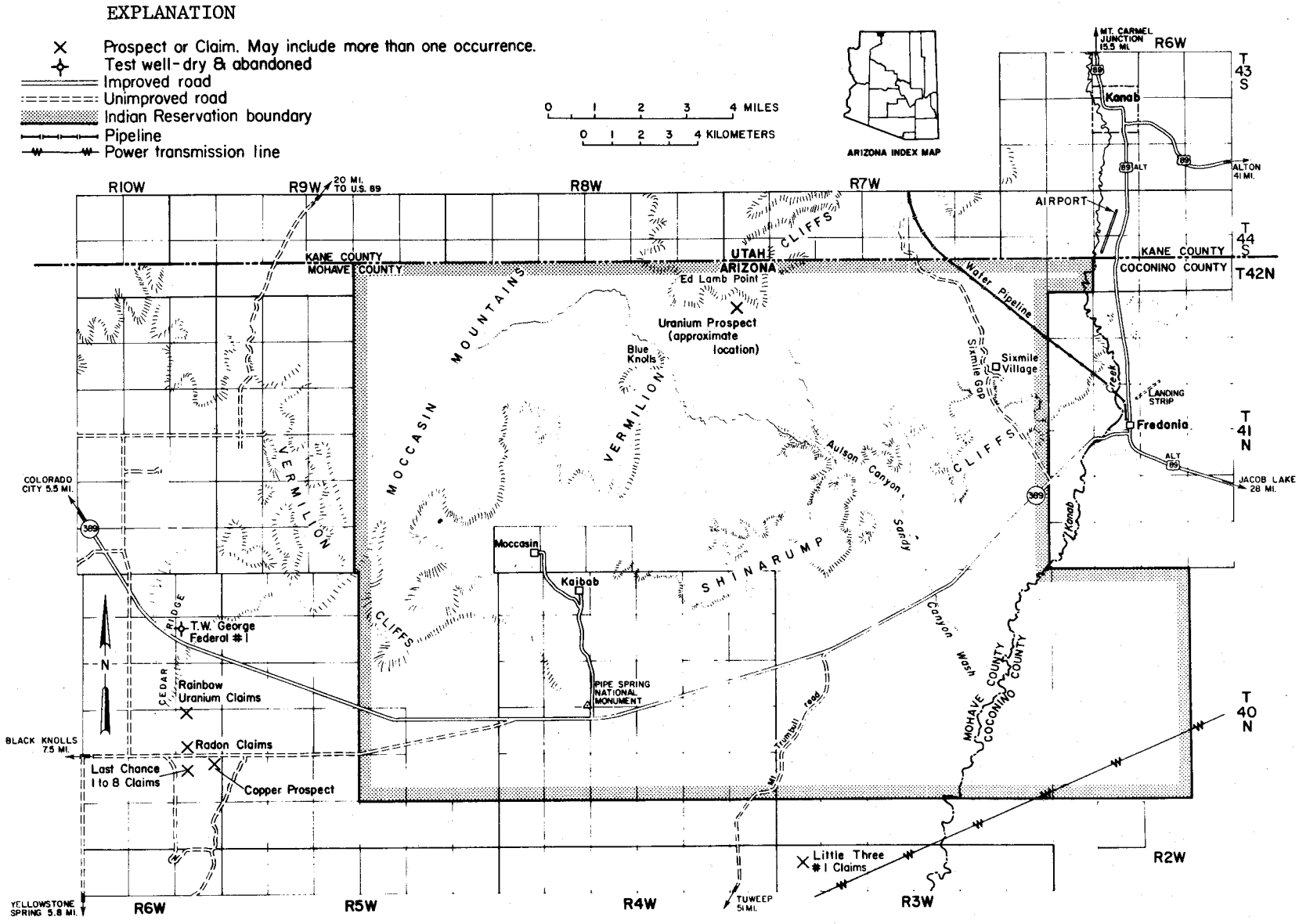

Figure 1. Index map of Kaibab Indian Reservation and vicinity, Coconino, and Mohave Counties, Arizona.

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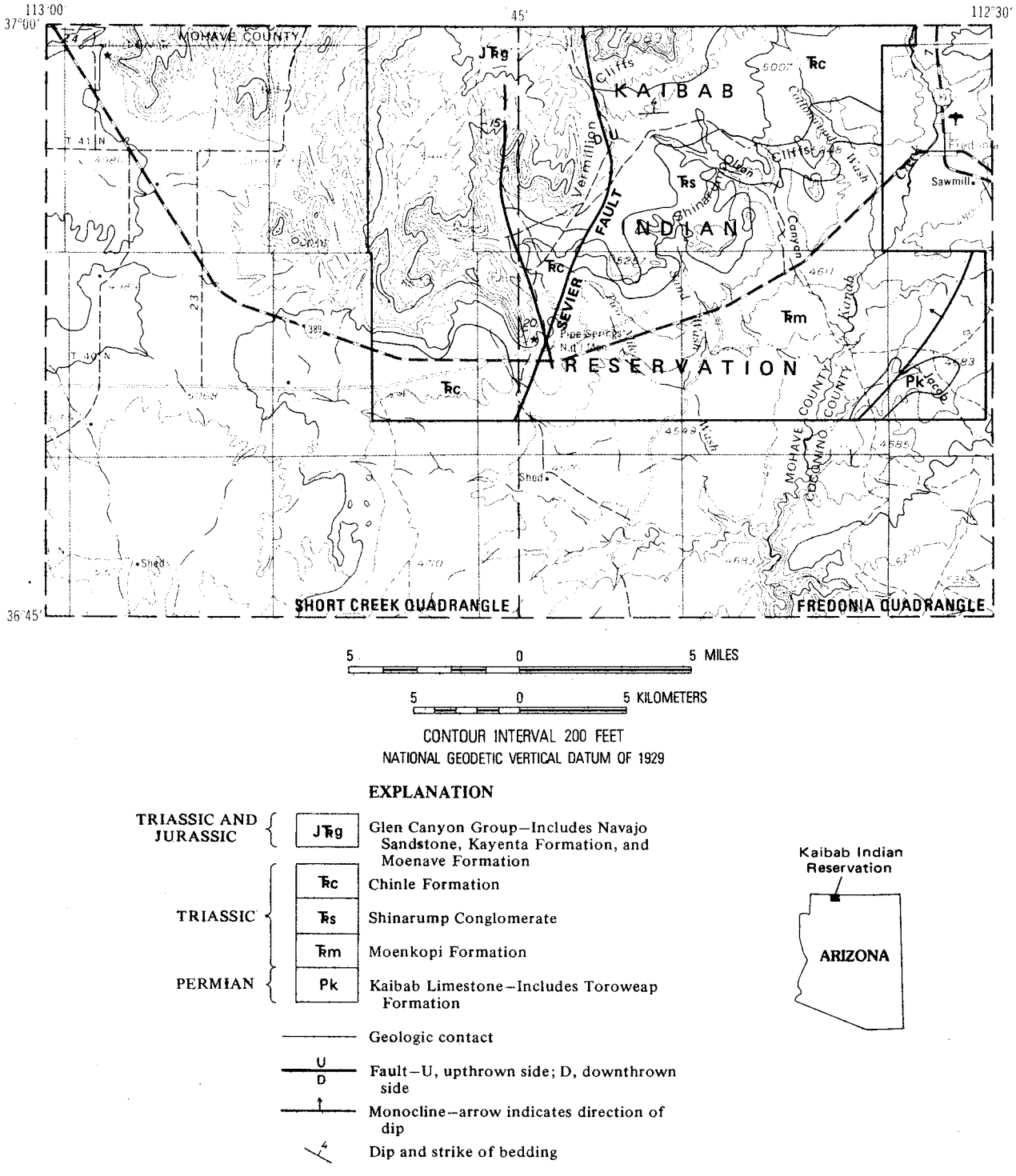

Figure 2. Geologic map of the Kaibab Indian Reservation.